EFFECT OF PARTICLE SIZE DISTRIBUTION ON SINTERING

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ABSTRACT

Studies have been performed examining the effect of the geometric standard deviation (lnσ) of lognormal distributions of tungsten powders on the resulting microstructure and sintering behaviour. Lognormal powder size distribution with controlled mean size and lnσ were produced by classifying bulk powders into narrow size cuts and reblanding in the desired proportions. Sintering behaviour of the blend was evaluated by comparing densification rates of samples with different lnσ values at each of several constant mean particle sizes. Specimen microstructures were evaluated in detail to better understand the observed sintering behaviour.

1. INTRODUCTION

The effect of particle size distribution on sintering is an area of surprisingly little research and understanding. The few prior theoretical treatments of this topic include that of Coble1 who consider one and two-dimensional particle arrays and Messing and Onoda2 who developed and tested a model based on packing inhomogeneity. Lacour and Paulus3 developed a complex model of sintering incorporating a hypothesized influence of size distribution on grain growth and the resulting effect on densification. Kuczynski's statistical model of sintering4 addresses size distribution effects although it has not yet been tested experimentally.

Experimental studies of particle size distribution are relatively sparse, perhaps due to the experimental difficulty of producing powder blends with controlled variations in distribution width. Several studies have been performed using biomodal mixtures of powders,5-7 and a few works have employed more realistic lognormal distributions with controlled widths.8-10 Barringer and Bowen11 have demonstrated enhanced sintering in carefully stacked compacts of near monosized powders.

There are bases for expecting effects of particle size distribution width on a number of aspects of powder compaction, sintering and densification, including the number of interparticle contacts, packing density, pore structure, channel closure and grain growth. The goal of the current work has been to examine the effects of controlled particle size distribution width on microstructural evolution and densification during sintering.
2. EXPERIMENTAL

The experimental studies reported here have included several sizes and shapes of powders including relatively coarse (45 µm) spherical copper powder and fine (< 10 µm) spherical and deagglomerated (polygonal) tungsten powders. Lognormally distributed powder blends of the different powder types were obtained by mixing controlled proportions of narrow powder cuts obtained by air classification. To determine the effect of the distribution width or geometric standard deviation, lnσ, on sintering, blends were produced with variations in lnσ value ranging from the narrowest powder cuts obtained, lnσ = 0.1, to very wide distributions with lnσ = 1.0. A linear programming technique was employed to compute the best combinations of powder cuts to obtain the desired distributions. Figure 1 illustrates a comparison of an aim and experimentally blended size distribution. The geometric mean particle size for a set of blends with varying width was always held constant.

A small amount of Rhoplex B-60A binder was added to the powder blends to prevent segregation. The bound powder mass was then granulated by mortar and pestle and sieved to obtain + 325 mesh granules. Specimens approximately 8 mm diameter by 3 mm thick, were pressed to a constant green density of 65 percent of theoretical in a steel die, presintered to debind then final sintered, both in hydrogen. The results of these studies are described below.

2.1. Coarse Spherical Powders

Blends of relatively coarse spherical copper powder were synthesized with constant geometric mean size by weight frequency of 45 µm, and lnσ values ranging from 0.1 to 1.0. These blends were prepared as described above and sintered at 950 °C in hydrogen for times ranging from 0.5 to 8 hr. Densification curves are illustrated in Fig. 2.a plotting sintering parameter versus time. The increase in densification rate with increasing lnσ value, apparent in Fig. 2.a, is better illustrated in Fig. 2.b. Figure

![Graph](image_url)

**Fig. 1.** Comparison of aim distribution and experimental blend for deagglomerated tungsten powder, 7 µm mean size, lnσ = 0.75.